SECTION 7.8 - SJV

ENTRAINED PAVED ROAD DUST
PAVED ROAD TRAVEL

June 2006
(Documenting changes made in 2003 for SJV only)

Emission Inventory Source Category
Miscellaneous Processes

Emission Inventory Codes (CES Codes) and Description

640-635-5400-0000	(83618)	Paved Entrained Road Dust - Freeways
640-637-5400-0000	(83626)	Paved Entrained Road Dust - Major Streets
640-639-5400-0000	(83634)	Paved Entrained Road Dust - Collector Streets
640-641-5400-0000	(83624)	Paved Entrained Road Dust - Local Streets
640-643-5400-0000	(89656)	Paved Entrained Road Dust - Local Streets (Rural)

METHODS AND DATA SOURCES

This method applies only to the San Joaquin Valley (SJV) Unified Air Pollution Control District. As part of the SJV District's 2003 PM10 State Implementation Plan, the paved road dust methodology and input data were updated as described in this methodology.

The paved road dust category includes emissions of fugitive dust particulate matter entrained by vehicular travel on paved roads. For the San Joaquin Valley, paved road dust emissions are estimated for five classes of roads. The five classifications are: 1) freeways/expressways, 2) major streets/highways, 3) collector streets, 4) local streets, and 5) local rural streets. The estimated SJV particulate matter emissions for paved road dust and the associated VMT for each county and road classification are shown at the end of the method in Table 4.

Changes in Method and Emission Estimates

There were three primary changes to the paved road dust emissions estimates for this San Joaquin Valley update. These include:

- Incorporation of 1999 locally developed paved road vehicle travel data, which was provided by regional Transportation Planning Agencies (TPAs) and split into appropriate road classifications.
- Update of vehicle travel data which allocates more vehicle miles traveled (VMT) to freeways than the prior ARB methodology (1997). The change reduced the overall SJV paved road dust estimate by about 25%, however, the total overall estimated VMT in the SJV was about the same as the ARB's 1999 estimate, which did not use the more refined TPA data.

- Incorporation of a rainfall correction factor to account for emissions reductions during rainy days. The change reduced the overall emissions estimate by about 2%.

Method Overview. Dust emissions from vehicle travel on paved roads are computed using the emission factor equation provided in the Fifth Edition of U.S. EPA's AP-42 document[1]. Inputs to the paved road dust equation were developed from California specific roadway silt loading and average vehicle weight data measured by Midwest Research Institute (MRI) in 1995[2]. Data compiled by the San Joaquin Valley Transportation Planning Agencies (TPAs) were used to estimate county specific VMT (vehicle miles traveled) data by road type classification. The paved road dust category does not explicitly estimate reentrained particulate matter produced by brake and tire wear, or PM exhaust emissions. However, some portion of these emissions are included in the paved road dust emission estimates due to the field sampling methods used to develop the paved road dust emission factor equation. Future updates will subtract-out these brake wear, tire wear, and exhaust emissions, which may decrease the overall PM paved road dust estimate by about five percent.

EMISSIONS ESTIMATION METHODOLOGY

Emission Factor. The emission factor used for computing entrained paved road dust emissions is from the U.S. EPA methodology provided in Section 13.2.1 of EPA's AP-42 document[1]. The emission factor equation is:

$$E = \left[k \left(\frac{sL}{2} \right)^{0.65} \left(\frac{W}{3} \right)^{1.5} \right] \times \left(1 - \frac{P}{4N} \right)$$

E is the particulate emission factor in units of pounds of particulate matter per VMT (vehicle miles traveled). The 'k' term is the particle size multiplier (used to compute PM_{10}, $PM_{2.5}$, etc., in the units of the emission factor). The 'sL' term is the roadway silt loading in grams/square meter, and 'W' is the average weight (tons) of vehicles on the road. The 'W' units (metric or English) correspond to k units).

The final term in the equation is the rainfall correction factor, which effectively reduces the emission factor based on the number of rainy days within the period of estimation. 'P' is the number of "wet" days with at least 0.254 mm (0.01 in) of precipitation. 'N' is the number of days in the averaging period, such as 365 days for annual or 30 days for monthly. The factor of "4" is in the denominator to help account for the drying of paved roads during the rain days, and for days when rain does not occur over the full 24-hour period. The ARB estimates are made on a monthly basis to account for seasonal variations.

For California, the base emission factor for paved road dust is computed in units of pounds of PM10 per VMT, so from AP-42, so k = 0.016 lb/VMT. The statewide average vehicle weight, W, is assumed to be 2.4 tons, based on an informal traffic count

estimated by Midwest Research Institute while they were performing California silt loading measurements[2]. The silt loading values are the based on averages of silt loadings measured by MRI in the South Coast Air Quality Management District and the San Joaquin Valley Unified Air Quality Management District[2]. Table 1 shows the *uncorrected* baseline emission factors used for the paved road dust emissions calculations and the various inputs. These baseline emission factors do *not* include the rainfall correction, which is applied independently for each county and each month.

Table 1. Baseline Uncorrected Paved Road Dust Emission Factors*

Road Type	Silt Loading (g/m^2)	Average Vehicle Weight (tons)	k (lb PM10/ VMT)	Base Emission Factor (lb PM10/ VMT	Base Emission Factor* (lb PM10/ million VMT
Freeway	0.02	2.4	0.016	0.0005738	573.79
Arterial	0.035	2.4	0.016	0.0008255	825.52
Collector	0.035	2.4	0.016	0.0008255	825.52
Local	0.32	2.4	0.016	0.0034788	3478.83
Rural	1.6	2.4	0.016	0.0099029	9902.92

*Note: Emission factors not corrected for rainfall

Activity Data. The activity data for paved road dust is vehicle miles traveled, or VMT. For the San Joaquin Valley counties, the VMT data were compiled by the local Transportation Planning Agencies (TPAs) for each county[3]. For the road dust calculations, VMT estimates from the year 1999 were used, subdivided into the five roadway classifications show above in Table 1.

Rainfall Correction. The rainfall correction is a new addition to this methodology. Incorporating the rain correction provided in AP-42 reduces emissions somewhat on those days in which there is measurable rainfall. For paved roads the emissions are not set to zero on rainy days because the roads may dry during the day and rains do not always fall for the full 24-hour period. Instead, on any day with measurable rain, the PM emission factor is reduced by ¼ of the full emissions factor. This correction calculation, which is calculated independently for each month and county, is too detailed to show here, but is provided in the emissions calculation spreadsheet[4] for the paved road dust method.

GENERAL METHOD ASSUMPTIONS

1. The current AP-42 emission factor assumes that road dust emissions are proportional to VMT, roadway silt loading, and average vehicle weight.
2. There are only a limited number of silt loading measurements for California, which will not fully represent the variability of the emissions throughout the San Joaquin Valley.
3. The methodology assumes that roadway silt loading, and therefore the emission factor, varies by the type of road.

4. It is assumed that the EPA particle size multiplier (i.e., the 'k' factor in the AP-42 equation) reasonably represents the PM10 size distribution of SJV paved road dust.
5. The average vehicle fleet weight is assumed to be 2.4 tons in the SJV.
6. For all road classifications, factors to forecast future growth in VMT were provided by the SJV Transportation Planning Agencies.
7. No adjustments were made to subtract out the portion of road dust that consists of vehicle exhaust, brake wear, and tire wear.

TEMPORAL ACTIVITY

For paved road dust, it was assumed that the base VMT on the roads is relatively consistent month-to-month. But, the emissions were distributed temporally over the year based on rainfall so that the months with more rain have somewhat lower paved road dust emissions. Table 2 below provides a summary of the monthly paved road dust temporal profiles for the SJV counties. The weekly and daily activities are estimated to have higher activities on weekdays and during daylight hours.

Table 2. SJV Counties Monthly Temporal Profile for Paved Road Dust.

County	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Fresno	8.21	7.42	8.27	8.20	8.60	8.42	8.73	8.73	8.38	8.59	8.13	8.32
Kern	8.21	7.41	8.29	8.15	8.59	8.43	8.71	8.71	8.36	8.61	8.16	8.36
Kings	8.23	7.42	8.30	8.16	8.58	8.44	8.72	8.72	8.37	8.58	8.16	8.33
Madera	8.19	7.41	8.26	8.19	8.61	8.40	8.75	8.75	8.40	8.61	8.12	8.33
Merced	8.07	7.38	8.27	8.22	8.66	8.46	8.80	8.80	8.45	8.62	8.09	8.18
San Joaquin	8.08	7.29	8.25	8.17	8.63	8.47	8.82	8.82	8.47	8.63	8.09	8.27
Stanislaus	8.15	7.37	8.24	8.17	8.64	8.43	8.79	8.79	8.43	8.62	8.10	8.27
Tulare	8.18	7.39	8.27	8.18	8.61	8.45	8.75	8.75	8.40	8.61	8.13	8.27

CES	Hours	Days	Weeks
ALL	24	7	52

SUGGESTED GROWTH SURROGATES

The growth factor for paved road dust is based on VMT growth in the SJV for each road classification. The VMT growth projections were supplied by the SJV transportation planning agencies.

COMMENTS AND RECOMMENDATIONS

Future updates to the method should include the subtraction of brake wear, tire wear, and vehicle exhaust emissions from the paved road dust estimates. These emissions are already inventoried separately as part of the mobile source emissions inventory. Any updates should use California specific exhaust, tire, and brake estimates, and not EPA defaults.

For the PM2.5 fraction of paved road dust, recent studies have shown that the PM2.5 emissions may be overestimated[5,6], therefore, the PM2.5 paved road dust size fractions should be appropriately adjusted during the next update. EPA has also performed analysis to develop adjustment factors to account for the fraction of geologic particulate matter that is deposited near the emissions source and is not entrained into the overall atmosphere. For future updates, these PM adjustment factors should be evaluated for their applicability to California and possibly incorporated into the emissions estimation method.

SAMPLE CALCULATIONS

The basic calculation for paved road dust estimates is relatively straightforward. For each road type in each county, the appropriate emission factor (EF) is multiplied by the appropriate vehicle miles traveled (VMT).

Emissions = Paved Road Dust EF x VMT

Table 2 below shows a summary of the emissions calculation for paved road dust in Fresno County. The VMT data were provided by the Fresno County Transportation Planning Agency, the emission factors are those shown previously in Table 1, and the base emissions are the product of the VMT and the EF.

Computing the rainfall corrected emissions is more complicated. To compute these emissions, the number of rainy days occurring each month was used to compute a rainfall corrected emission factor for each month and for each county[7]. These monthly factors were then used to estimate monthly road dust emissions, which were summed to compute annual paved road dust PM10 emissions corrected for rainfall. The details of these calculations are provided in the supporting spreadsheet[4]. The updated 1999 paved road dust estimates for counties in the SJV Air District are shown in Table 4.

Table 3. Example of Calculating Paved Road Dust Emissions

	Fresno County 1999 VMT (million/year)	**Base Emission Factor** (lb PM10/ million VMT	**Base Emissions** (PM10 tpy)	**Rainfall Corrected Emissions** (PM10 tpy)
Freeway	2138.5	573.8	613	597
Arterial	3286.5	825.5	1357	1320
Collector	748.0	825.5	309	300
Local	371.9	3478.8	647	629
Rural	211.0	9902.9	1045	1016

REFERENCES

1. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors, AP 42, Fifth Edition, Volume I, Chapter 13: Miscellaneous Sources, Section 13.2.1 Paved Roads, December 2003. http://www.epa.gov/ttn/chief/ap42/ch13/index.html

2. Muleski, Greg. Improvement of Specific Emission Factors (BACM Project No. 1), Final Report. Midwest Research Institute. March 29, 1996.

3. Anderson, Cari. Data compiled from SJV Transportation Planning Agencies. Provided to P. Gaffney, ARB, via email on 2/27/2003 by Cari Anderson, Earth Matters, canderson@earthmatters.net, http://www.earthmatters.net

4. Gaffney, Patrick. Paved Road Dust Emissions Estimation Spreadsheet. California Air Resources Board. February 2006 (based on original work in 2002). Contact: pgaffney@arb.ca.gov

5. Cowherd, C., Analysis of the Fine Fraction of Particulate matter in Fugitive Dust, Final Report. October 12, 2005. Midwest Research Institute. MRI Project No. 110397. http://www.wrapair.org/forums/dejf/documents/fffd/Final_Fine_Fraction_Dust_Report.pdf

6. Cowherd, C., Proposed Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors. November 7, 2005. Midwest Research Institute. MRI Project No. 110397

7. Western Region Climate Center. Monthly average number of days with measurable precipitation (>=.01 inches)
http://www.wrcc.dri.edu/htmlfiles/ca/ca.01.html
NOAA/NWS Cooperative Observer Network Active Stations as of Jan. 1998
http://www.wrcc.dri.edu/inventory/coop04.html

UPDATED BY

Patrick Gaffney
June 2006
pgaffney@arb.ca.gov

Table 4. 1999 Paved Road Dust PM10 Emission Estimates for the San Joaquin Valley Air Quality Management District

County		VMT (million/year)	Base Emissions (PM10 tpy)	Rain Adj. Emissions (PM10 tpy)
Fresno	Freeway	2138.5	613.5	596.8
10	Arterial	3286.5	1356.6	1319.6
	Collector	748.0	308.8	300.3
	Local	371.9	647.0	629.3
	Rural	211.0	1045.0	1016.5
	Total	**6,756**	**3,971**	**3,863**
Kern	Freeway	2519.8	722.9	704.7
15	Arterial	2285.4	943.3	919.5
	Collector	128.7	53.1	51.8
	Local	169.7	295.1	287.7
	Rural	176.6	874.4	852.3
	Total	**5,280**	**2,889**	**2,816**
Kings	Freeway	361.2	103.6	100.9
16	Arterial	387.2	159.8	155.7
	Collector	28.5	11.8	11.5
	Local	100.9	175.4	170.9
	Rural	245.7	1216.7	1185.0
	Total	**1,124**	**1,667**	**1,624**
Madera	Freeway	494.0	141.7	137.6
20	Arterial	425.0	175.4	170.2
	Collector	198.3	81.8	79.4
	Local	38.3	66.6	64.7
	Rural	104.1	515.3	500.1
	Total	**1,260**	**981**	**952**
Merced	Freeway	714.2	204.9	197.7
24	Arterial	1134.5	468.3	451.9
	Collector	323.6	133.6	128.9
	Local	27.3	47.5	45.9
	Rural	57.0	282.3	272.4
	Total	**2,257**	**1,136**	**1,097**

County		VMT (million/year)	Base Emissions (PM10 tpy)	Rain Adj. Emissions (PM10 tpy)
San Joaquin 39	Freeway	2705.9	776.3	747.2
	Arterial	1682.5	694.5	668.4
	Collector	653.7	269.8	259.7
	Local	190.6	331.6	319.1
	Rural	125.5	621.4	598.1
	Total	**5,358**	**2,694**	**2,593**
Stanislaus 50	Freeway	1023.0	293.5	283.7
	Arterial	1242.3	512.8	495.7
	Collector	1333.1	550.3	531.9
	Local	97.8	170.2	164.5
	Rural	55.8	276.1	266.9
	Total	**3,752**	**1,803**	**1,743**
Tulare 54	Freeway	877.5	251.8	244.4
	Arterial	1674.9	691.3	671.1
	Collector	157.3	64.9	63.0
	Local	350.6	609.8	592.0
	Rural	129.7	642.1	623.3
	Total	**3,190**	**2,260**	**2,194**

	VMT (million/year)	Base Emissions (PM10 tpy)	Rain Adj. Emissions (PM10 tpy)
Total 1999 SJV Paved Road Dust PM10 (tons/year)	**28,976**	**17,401**	**16,880**